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CIRCULAR No. 23.

United States Department of Agriculture.

BUREAU OF ANIMAL INDUSTRY.

WASHINGTON, D. C., *March 12, 1898.*

The accompanying paper prepared by Dr. Victor A. Nörsgaard, Chief of the Pathological Division, entitled *Blackleg: Its Nature, Cause, and Prevention*, is respectfully recommended for publication as Circular No. 23 of this Bureau. As a matter of convenience, the author has included essential features of Circular No. 6, *Black Quarter*, by the undersigned; Circular No. 20, *Preventive Vaccination against Blackleg*; and Circular No. 21, *Direction for Use of Blackleg Vaccine*, both of the latter prepared by Dr. Nörsgaard.

Respectfully,

D. E. SALMON,
Chief of Bureau.

Approved:

JAMES WILSON,
Secretary of Agriculture.

BLACKLEG: ITS NATURE, CAUSE, AND PREVENTION.

By VICTOR A. NÖRGAARD,
Chief of Pathological Division.

GENERAL NATURE OF DISEASE AND ANIMALS AFFECTED.

Blackleg, also known as "black quarter," "quarter ill," and "symptomatic anthrax," is an acute infectious disease caused by a specific germ, the blackleg bacillus. It is characterized by extensive alterations in the parts affected, accompanied by a distention of the tissues due to the formation of gas.

SPECIES OF ANIMAL AFFECTED.

Cattle contract the disease on pastures, and this is also stated to be the case with sheep and goats. All three species of animals can be artificially inoculated with blackleg, though cattle and sheep are more readily inoculated than goats. Guinea pigs are very susceptible. When horses, asses, and white rats are inoculated, the only result noticed is a local swelling which in time disappears. Some animals, such as swine, dogs, cats, rabbits, and black rats, enjoy a natural immunity from this disease, and attempts to inoculate them are therefore unsuccessful. Man also is unaffected by the blackleg bacillus.

AGES OF CATTLE AFFECTED.

Blackleg is more common in cattle from 1 to 2 years old than in cattle of any other age; occasionally animals from 6 months to 1 year old or from 2 years to $2\frac{1}{2}$ years old may be attacked, and in rare cases calves under 6 months or cattle over $2\frac{1}{2}$ years may be affected. The comparative freedom of calves from the disease is to be explained in two ways: First, calves are naturally less susceptible to blackleg than are older animals, as has been shown by experimental inoculation; second, animals feeding on milk are less exposed to infection than are grazing animals.

MANNER OF INFECTION.

Blackleg is not a contagious disease, that is, one animal will not contract it by simply coming in contact with another. As a rule the germ is introduced into the system through some wound or abrasion of the skin or mucous membranes, such as may be received on the skin from a barbed wire fence or from stubbles or briars in the pasture, or from any hard, sharp substance which punctures the lining of the mouth or intestinal tract.

CHARACTERISTICS OF THE BACILLI.

The blackleg bacilli are not able to multiply in the presence of oxygen; in technical language, they are anaerobic. This explains the fact that while they do not develop on parts of the body exposed to free air, such as the skin and mucous membranes, the germs find the conditions necessary to their growth in the parts underneath the skin, as the underlying connective tissue, to which the air does not have access. The second point to be noticed in connection with the bacilli is that one of the ends of each bacillus is enlarged. This enlargement is due to the formation of a so-called "spore," which is a small portion of the germ surrounded by a hard shell-like substance; a structure of this kind is naturally very resistant to external influences, being able to withstand heat, cold, light, and other unfavorable conditions, and even decomposition in a dead body, which would more quickly result in the destruction of unprotected bacilli. With such a spore stage to protect it, the blackleg germ may exist for a long time outside of the body, and it is very difficult to eradicate the disease from a pasture which has once become infected. Experience shows that the spores may exist almost indefinitely in the ground, and that animals may become infected on the same pasture year after year. It is claimed that cultivating the soil for several years will effectually eradicate the disease, but with large areas which are unfit for anything except pasturage this method is of course impracticable.

SYMPTOMS.

The symptoms of blackleg are so characteristic that the disease is easily recognized. The first symptoms may be either of a general or of a local nature, though more frequently the latter is the case. The general symptoms are high fever, loss of appetite, and suspension of rumination, followed by great depression. Respiration becomes accelerated; the animal moves around with difficulty, frequently lies down, and, when water is near at hand, drinks at short intervals and but little at a time. The visible mucous membranes are at first dark red and congested, but they change in the course of twelve hours to a dirty leaden or purplish color.

The most important diagnostic feature is the development of a tumor or swelling under the skin. This swelling may appear on any part of the body and limbs, except below the knee or hock-joint. It is frequently seen on the thigh or shoulder, and, owing to the extensive discoloration of the swollen parts, as observed after the animal has been skinned, the disease has been popularly named "blackleg" or "black quarter." Tumors may also appear on the neck, the chest, the flank, or the rump. At first they are small and very painful. They increase rapidly in size and may in a few hours cover a large portion of the body. One or more of these tumors may form simultaneously, and when in close proximity to each other may become confluent. The neighboring lymph glands become considerably swollen.

If slight pressure is exerted on the tumor a crackling sound is heard, and percussion gives a clear, resonant tone, due to the collection of gas in the affected tissue. The tumor is cool to the touch and painless in the center; the skin over it is dry and parchment-like. When the tumor is lanced a frothy, dark-red fluid is discharged. If the incision is made while the animal is alive or immediately after death, there is no offensive odor to the discharge, but decomposition takes place very soon after death. No pain is manifested when the center of the tumor is lanced, but as soon as the knife reaches the warm, inflamed part the animal will bellow loudly and flinch.

The swellings usually appear before the general symptoms, and they may even reach such an extent as to cause complete paralysis of the affected part while the animal still looks bright and has a good appetite. This condition is, however, of short duration. As the swellings increase in size the general symptoms become more intense. The temperature may reach 107° F., while the respiration may exceed 140 per minute. The animal is unable to rise; the extremities become cold, and sometime before death the temperature falls and may become subnormal. There is trembling of the muscles, which, as death approaches, may develop into violent convulsions.

APPEARANCE AFTER DEATH.

The skin over the swelling is affected with dry gangrene. The connective tissue beneath the skin is infiltrated with blood and bloody serum, and is distended with gas. The affected muscles are dark brown or black, are easily torn, and the spaces surrounding them are filled with bloody liquid and gas. The color is deepest at the center, shading off toward the edges, and becomes brighter by contact with the air. On compression thick blood escapes, which is charged with gas and has a disagreeable odor. The gas of the tumor is combustible and burns with a blue flame, being, according to Bollinger, carbureted hydrogen. The abdominal cavity sometimes contains a considerable quantity of bloody effusion. The mucous membrane of the intestine may be congested or inflamed and the contents of the bowels may be covered with blood. The liver is congested, but the spleen is always normal. The flesh decomposes rapidly, and the carcass is soon greatly swollen by the accumulation of gas under the skin and in the body cavities.

It is sometimes desirable to determine whether an animal is affected with black quarter or with anthrax tumor, or with a swelling caused by the bacillus of malignant oedema. The anthrax tumor may be distinguished by the hardness and solidity of the tumor, and by the fact that it contains no gas. The spleen is enlarged in anthrax, and is unaffected in black quarter. It is difficult to distinguish between the swellings of black quarter and malignant oedema, since they resemble each other very closely, and both are distended with gas. Malignant oedema, however, generally starts from a wound of considerable size; it often follows surgical operations, and does not usually result from the small abrasions and pricks to which animals are subjected in pastures.

TREATMENT.

Owing to the rapid and violent course of the disease, treatment is of little or no value. Numerous remedies have been proposed and tried, but the cases of recovery on record are exceedingly rare. It has been suggested to make a number of deep incisions into the affected part and to apply some strong disinfectant to the wounds, but even such radical measures have proved to be of very little value, and only tend to cause the animal unnecessary suffering. Furthermore, when this treatment is undertaken in a pasture, the animal is liable to scatter the discharge from the wounds over large areas, and thus spread the infection. It is, therefore, strongly recommended never to attempt this treatment except when the animal is confined in a place which can be thoroughly disinfected.

DISPOSITION OF BLACKLEG CARCASSES.

All animals which die from blackleg should be immediately burned before they are attacked by vermin or birds of prey, as these may scatter the infection. In order thoroughly to destroy a carcass, it should be placed upon two logs and a cord of dry wood heaped over and around it. If one fire does not destroy it completely, another should be built over the parts remaining. In a pasture where wood is scarce, the carcass may be buried; in this case the hole in the ground should be at least 6 feet deep and the carcass should be well covered with lime before the earth is filled in. Lime should also be scattered freely over the grave and also over the space where the animal was lying before being buried. No effort should be spared to make sure that infection from the dead animal is impossible. It is due to neglect of these important precautions that blackleg has gained such a foothold in certain parts of this country as almost to make cattle raising unprofitable.

PREVENTIVE VACCINATION.

For several years frequent reports have come to this Bureau concerning the great mortality from blackleg among young stock in many widely separated districts of the United States. In some of the Southern and Western States especially, the annual losses from this fatal disease have been so great as easily to exceed the losses of cattle from all other causes combined. These losses have been particularly felt by the progressive stock growers, as by far the largest percentage of the calves which became affected were either full-blood or highly graded animals, which appear to be more susceptible to blackleg than the ordinary common-bred stock. As the continued existence of blackleg has a very detrimental effect upon the cattle industry in general, and especially upon those stock owners who, through untiring efforts and great expense, have endeavored to improve their herds, an investigation has been made by this Bureau with a view to devising some measure through which the steadily increasing losses might be arrested or reduced as much as possible.

In Europe, where the disease has long prevailed, the annual losses in certain badly infected districts became so disastrous that cattle raising had to be abandoned. About fifteen years ago three French scientists, Arloing, Cornevin, and Thomas, succeeded in producing a blackleg vaccine, which is now extensively used in many countries where the disease prevails to a serious extent. The method of its use consists in injecting into each calf two doses of highly attenuated blackleg virus, with an interval of ten days between the two inoculations. The first inoculation is made with a very mild vaccine, the

so-called "first lymph." In each case the vaccine is introduced by means of a hypodermic syringe under the skin on the lower part of the tail. This method, which is very inconvenient, especially where a large number of animals are to be treated, was later modified by a German scientist, Kitt, who reduced the process to a single injection with less attenuated virus, and who chose the loose skin on the side of the chest, just behind the shoulder, for the point of inoculation. Kitt's method has been adopted to a very large extent in eastern Europe and northern Africa with very satisfactory results, and it has, for that reason and on account of its simplicity, been taken as the basis for the investigations made by this Bureau.

A "single vaccine" has been prepared in the pathological laboratory of the Bureau, and subsequently tested on a large number of calves in Texas, both common and high-grade stock, and the results warrant the conclusion that this vaccine is in every way satisfactory. It is desired, however, before distributing the vaccine to stock owners in general, to obtain records of several thousand successful vaccinations. For this purpose a quantity of vaccine will be distributed to such parties as may desire to make preliminary vaccinations and report the results to this Bureau. Explicit instructions will be sent with the vaccine to secure uniformity of operation and to assist persons who are without previous experience in the vaccinations. Persons lacking the necessary outfit should procure one if they propose to test the vaccine. This outfit can not be supplied by the Department of Agriculture, but must be purchased of some house which supplies such articles.¹

DIRECTIONS FOR USE OF BLACKLEG VACCINE.

The blackleg vaccine, as prepared by this Bureau, consists of a brownish powder, which is put up in packets containing either ten or twenty-five doses each. To prepare this powder in such a way that it may be injected hypodermically, it is necessary to obtain certain implements, which, together with the hypodermic syringe, are known as a vaccinating outfit. This consists of a porcelain mortar with pestle, a small glass funnel, and a measuring glass. For filtering the vaccine, we have found absorbent cotton to be most suitable. Figure 1 is an illustration of the vaccinating outfit recommended by

¹A complete vaccinating outfit, including hypodermic syringe, can be obtained from Z. D. Gilman, 627 Pennsylvania avenue N. W., Washington, D. C., for the sum of \$4. The outfit is prepared by the firm named in accordance with the plans of this Bureau, to meet the temporary demand that may arise in introducing this vaccine. If vaccination should be extensively adopted as a preventive of this disease similar outfits will, no doubt, be for sale by other dealers furnishing this class of supplies. Until this may be the case, the unusual course of mentioning a dealer by name in a Department publication is followed.

this Bureau. All of the utensils, including the hypodermic syringe and a package of absorbent cotton, are fitted in a strong, polished, oak box, which by means of an adjustable wire loop serves also as a support for the funnel when the vaccine is filtering. The syringe, two hypodermic needles, and an extra glass barrel are packed in a separate small metal box. The syringe, needles, and glass barrel are attached by means of clamps to a loose metal plate which fits snugly into the bottom of the box. This arrangement serves to keep the different parts together when the outfit is being sterilized.

The syringe (fig. 2) has a capacity of 5 cubic centimeters, and the piston is graduated from one to five, each division being subdivided with half and quarter notches. The screw regulator (fig. 2, *sr*) may be placed at any mark on the piston, and thus insure that the animal to be vaccinated receives only the exact dose intended for it. The

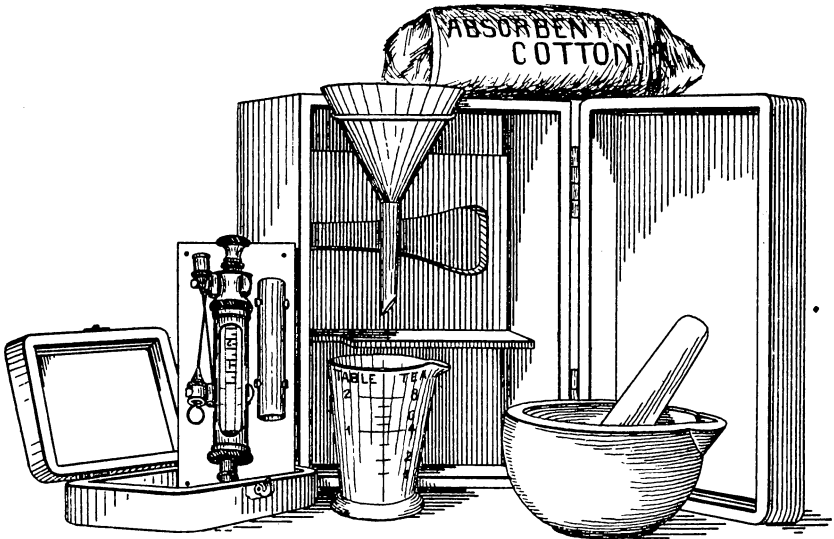


FIG 1.—Vaccinating outfit.

plunger (fig. 2, *pl*) is made of rubber; it should fit air-tight in the glass barrel and still be susceptible of being moved up and down smoothly. By means of the milled head (fig. 2, *mh*) at the free end of the piston the rubber of the plunger may be expanded or contracted, simply by screwing the head to the right or left. By this arrangement a close fit may always be obtained without taking the springs apart. If the plunger should become dry or for other reasons not move smoothly up and down in the barrel, it is necessary to unscrew the milled cap *c* and pour a drop of glycerine into the barrel. For this purpose a small bottle of glycerine is furnished with each outfit; oil or grease should never be used, as these substances destroy the rubber. Extra washers to be placed inside of the cap at each end of the glass barrel are also to be found in the syringe box.

It is of the greatest importance that the syringe be perfectly tight, in order that not a drop of vaccine may escape, except through the point of the needle. If a leak occurs, unscrew the cap of the syringe, withdraw the glass barrel, and replace the old washers with new ones.

In order to prevent the plunger and washers from drying out, the small loose cap *lc* should always be tightly adjusted to the peg *p* when the syringe is not in use.

The hypodermic needles should be kept very sharp at the point, in order to pass easily through the skin, and when not in use should have a fine brass wire passed through each to prevent rusting on the inside. Before using the syringe, it should be thoroughly tested with pure water to ascertain that it is in perfect working order. To this end, fill the syringe slowly by withdrawing the piston. If the syringe is perfectly tight, it should fill completely; if it contains air bubbles, turn it with the point upward and press the piston until the water comes out of the point, then refill. The same precaution must be taken when filling the syringe with vaccine.

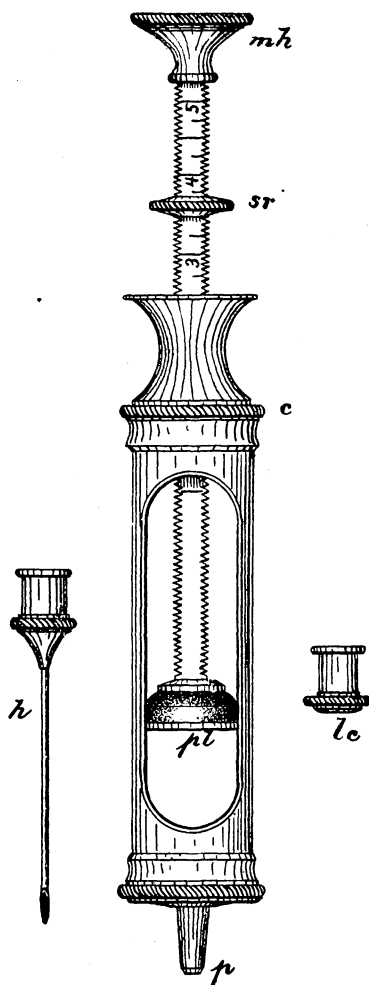


FIG. 2.—Hypodermic syringe.

STERILIZATION OF UTENSILS.

Before preparing the vaccine all the utensils, together with the hypodermic syringe, must be thoroughly sterilized. This is done by putting the mortar, pestle, measuring glass, and the metal plate, with the syringe and needles attached, in a pan of cold water,

placing all over the fire. After boiling for ten minutes, the pan with the contents should be allowed to cool off slowly; then remove the utensils from the water and wipe them dry with a clean linen cloth which has been previously boiled. When the vaccine has been prepared the utensils should again be thoroughly cleansed and replaced in the box. After injection, the syringe and needles must be washed with a 5 per cent solution of carbolic acid, carefully wiped, and the brass wire adjusted in the needles.

PREPARATION OF THE VACCINE.

Place the contents of one packet of the vaccine in the porcelain mortar and add a few drops of boiled water. (The water must have been previously boiled and allowed to cool.) Work the powder thoroughly with the pestle and then add, little by little, as many cubic centimeters of water as the packet contains doses. As the syringe contains exactly 5 cubic centimeters, it may be used for measuring the water. A packet containing 10 doses of the vaccine should be dissolved in two syringes full of water, and one containing 25 doses in 5 syringes full. Care should be taken that the syringe is full every time. To filter the vaccine place the wooden box on end, as shown in the illustration, and adjust the wire loop in the two eyelets. Place in the funnel a small piece of absorbent cotton and press it lightly into the upper end of the neck, sufficient to keep it in place; moisten the cotton with a few drops of boiled water and let it drip off. Stir the mixture in the mortar thoroughly and, before it has had time to settle, pour it into the funnel under which the measuring glass has been placed. The solution should be of a light-brown color; if perfectly clear, the cotton has been pressed too tightly into the neck of the funnel.

When a large number of animals are to be vaccinated at the same time, three or four packets of the vaccine may be dissolved at once, care being taken that the requisite amount of water is used, as otherwise the solution will be too strong or too weak. When the vaccine is prepared at home, a small, sterilized-medicine bottle may be substituted for the measuring glass under the funnel. The stopper of this bottle, if cork, must have been thoroughly soaked in boiled water. The vaccine is carried in the bottle to the place of operation, where it may be transferred, a little at a time, to the measuring glass; from this it may conveniently be drawn into the syringe. In doing this it is of importance to remember that, when standing for some time, a slight sediment will form at the bottom of the vessel or bottle, and the vaccine should therefore always be well shaken or stirred before the syringe is filled. When some time elapses between the vaccination of two animals, and the syringe still contains one or more doses of vaccine, the operator should turn the syringe up and down frequently to insure an even distribution of the germ-carrying particles throughout the vaccine.

No more vaccine should be prepared at one time than can be used the same day. While the vaccine powder will remain unchanged for more than a year, the solution deteriorates very quickly, and must be used within twenty-four hours after it is made.

ANIMALS TO BE VACCINATED.

Calves, as a rule, should not be vaccinated until they are half a year old. Under this age they are practically immune against

blackleg, and it has been claimed that when vaccinated before they are half a year old they are liable to lose the artificial immunity induced by means of vaccination and become susceptible again. Animals more than $2\frac{1}{2}$ years old, as stated above, are seldom affected, and the mortality among them is so small that it makes vaccination unprofitable. It is the calves between one-half and $2\frac{1}{2}$ years old which should be vaccinated.

Vaccination has no ill effect on calves half a year old, but it should be a rule that when very young animals are vaccinated they should be revaccinated the following year.

Vaccination and castration should not be performed at the same time. Castration is always a severe operation, and in some cases decreases the vitality of the animals to such an extent as to make them unable to resist the effect of the vaccination. The same principle applies to all surgical operations (castration, spaying, dehorning, etc.) as well as to those cases where the constitution of the animal has been impaired from injuries external or internal.

Ten days or two weeks should be allowed to pass after vaccination before any surgical operation is undertaken, and, if performed before vaccination, ample time should be allowed for the part to heal and for the animal to regain its lost strength.

THE DOSE TO BE INJECTED.

Animals one year old or over are injected with a full dose of vaccine; that is, one cubic centimeter of the solution. Under this age the dose may be reduced to one-half or three-fourths of a full dose, according to the size and development of the animal. Less than one-half a dose should never be injected. In determining the dose for each animal more consideration should be given to the size and development of the animal than to its exact age.

HOW TO OPERATE.

When the animals to be vaccinated are gentle and accustomed to being handled, vaccination may be performed on the standing animal. Range cattle or other half-wild animals must be thrown or secured, as in a dehorning chute.

The most convenient place to inoculate is on the side of the neck, just in front of the shoulder, where the skin is loose and rather thin. If the animals are secured in a dehorning chute, it is easier to vaccinate them on the side of the chest just behind the shoulder.

All animals should be vaccinated on the same side and marked in such a way that they may be easily recognized. The best way to mark them is to use a small branding iron in the shape of a V, or to fasten a metal tag in the ear.

When the animal is secured, fill the syringe with vaccine and ascertain that it contains no air bubbles; then insert the hypodermic needle by grasping a fold of the loose skin between the thumb and forefinger of the left hand and pushing the needle through the skin. The operator now adjusts the peg of the syringe tightly in the cap of the needle and injects the dose, which has been previously limited by the screw regulator on the piston. The needle is then withdrawn without detaching the syringe, and, to prevent any of the vaccine from escaping through the hole of injection, the skin is pressed tightly around the receding needle. The latter is then detached, the regulator screwed back to its proper place, according to the size and age of the animal to be next vaccinated.

When a large number of cattle are to be vaccinated, it is of importance to have a sufficient number of assistants, as otherwise the process becomes exceedingly tiresome and fatiguing both to the operator and to the assistants. The herd to be treated is confined in a pen, from which a small number, from five to ten, according to the number of assistants at hand, are driven into a smaller pen, where the assistants throw them and hold them down. Very wild range cattle must be lassoed, but graded or fine stock, being less unmanageable, should be seized by the head and thrown. The first method requires a larger pen, but when the assistants are skillful in handling the lasso it is by far the quickest way. The animals should all be thrown on the same side. One assistant sits across the side of the thrown animal, with his face toward its head and holding the upper foreleg pulled back and up. When secured in this way it is almost impossible for a well-grown yearling to free itself.

With older and stronger animals it is safer to have two men to hold each, as an animal which succeeds in getting up before all have been injected and marked, will frequently make things very unpleasant for the operator and assistants, chasing them from the pen and necessitating a repetition of the whole process.

The operator should have an assistant to insert the needle, while he himself adjusts the regulator. After inserting the needle, the assistant lifts the skin fold, presenting the cap of the needle so that the operator may easily grasp it and attach the syringe. In this way from 90 to 100 head of yearling calves may be vaccinated in one hour, with ten men to handle the animals and one assistant to insert the needle; but such a rate can only be maintained for a limited time without changing the men. With one set of men not more than 400 or 500 head should be vaccinated in one day, according to the age and size of the animals. Where a dehorning chute is used a much larger number may be vaccinated.

SYNOPSIS OF VACCINATION PROCESS.

- (1) Sterilize outfit by boiling.
 - (2) Place one powder in the mortar and add a few drops of water.
 - (3) Work the mixture well with the pestle.
 - (4) Add two to five syringes full of water, according to the size of the packet, and stir well.
 - (5) Place cotton in glass funnel and moisten it with water.
 - (6) Filter vaccine into the glass or bottle.
 - (7) Secure the animal to be injected.
 - (8) Insert the needle through the skin.
 - (9) Fill the syringe and adjust the screw regulator on the piston.
- If the first animal is a yearling or older, place regulator at No. 1.
- (10) Fit the peg of the syringe into the cap of the needle and inject the dose.
 - (11) Withdraw syringe and needle together. If the syringe is removed from the needle before this has been drawn out of the skin, some of the injected vaccine will flow back through the needle and be lost. In this case the animal does not get its full dose and will, consequently, be insufficiently protected.

THE RECORD TO BE PRESERVED.

In the course of six months a blank for recording the results will be sent to each person who undertakes these experiments. He will, therefore, be good enough to keep an accurate account of the number of animals vaccinated; their ages; the number, if any, of those which die from the vaccination; and the number of vaccinated animals which die from blackleg. This information should be forwarded to the Bureau, addressed as follows:

Dr. D. E. Salmon,

Chief of Bureau of Animal Industry,

U. S. Department of Agriculture,

Washington, D. C.

All applications for blackleg vaccine should be similarly addressed. A regular application blank will be mailed to any stock owner who so requests, and in accepting the vaccine he pledges himself to report the results.

Attention is called to the rule that under no circumstances will blackleg vaccine be sent to any one person for distribution to others, except in the case of State officials or sanitary officers. Each stock owner must apply directly to this office for the amount of vaccine required for his own cattle, and this will in each case be sent to him direct.